U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Lightweight Materials for Vehicles
Needs, Goals, and Future Technologies

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Vehicle Technologies Program

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Report Documentation Page

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Vehicle Technologies Program

Vehicle Technologies Program

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*detailed to another location

Lightweight Materials Breakdown

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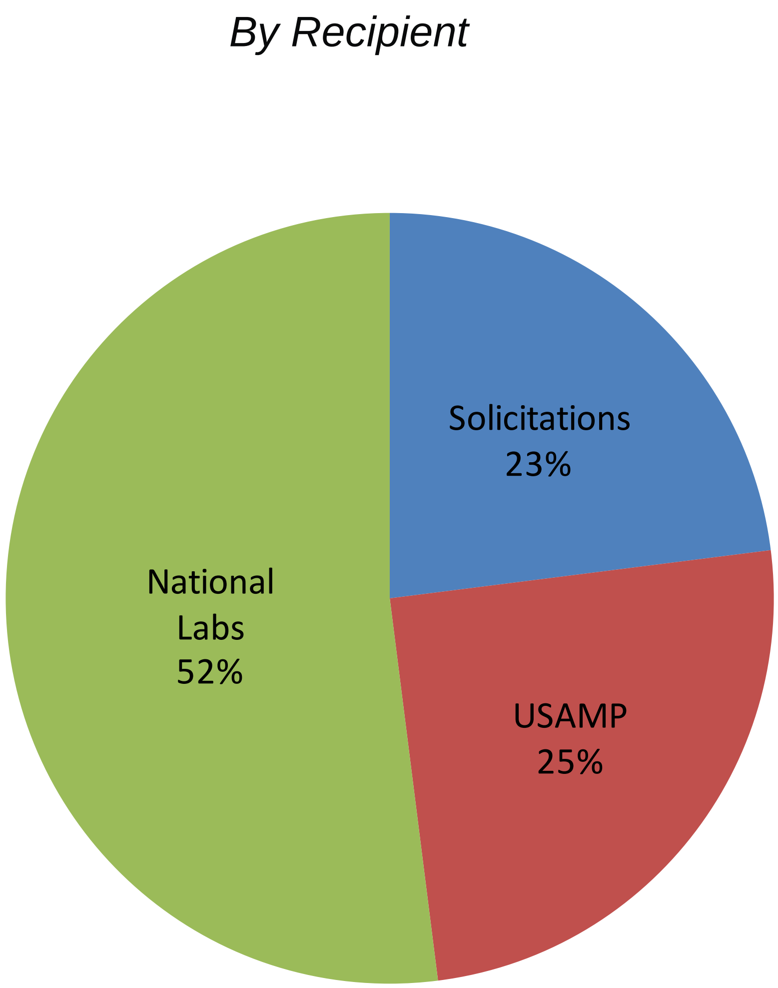

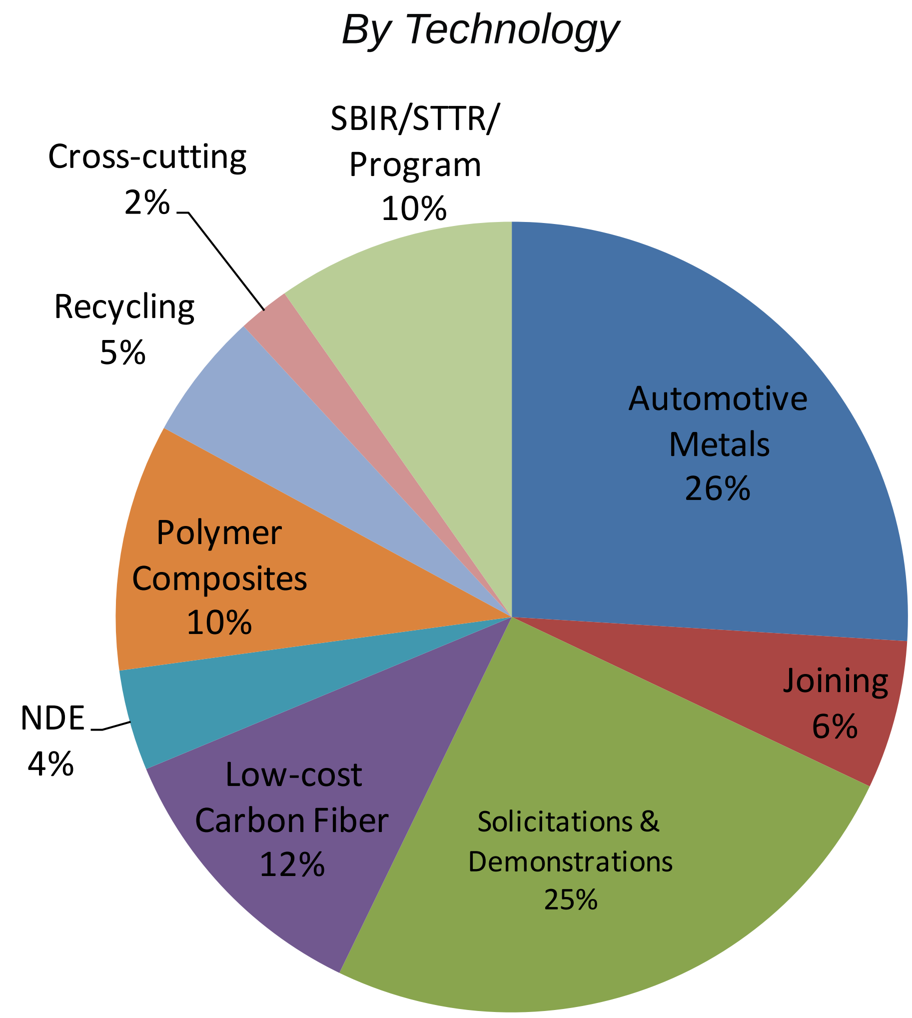

Total FY 2010 Funding: $30,652,000

Why Lightweight?

Lightweight Goals

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Key administration goal relevant to Vehicle Technologies

- Reduce greenhouse gas emissions by 40% by 2030 and 80% by 2050 (compared to a 2002 baseline)

Materials

Average vehicle weight reduced by 50%

HE Systems

Electric drive production cost reduced to $12/Kw

Fuels

Research into 3rd Gen biofuels expanded

ACE R&D

Gasoline engine fuel economy improved by 25%

2030

57 mpg fleet, 7% LDV VMT electrified

→

2050

111 mpg fleet, 24% total LDV VMT electrified

Why Lightweight?

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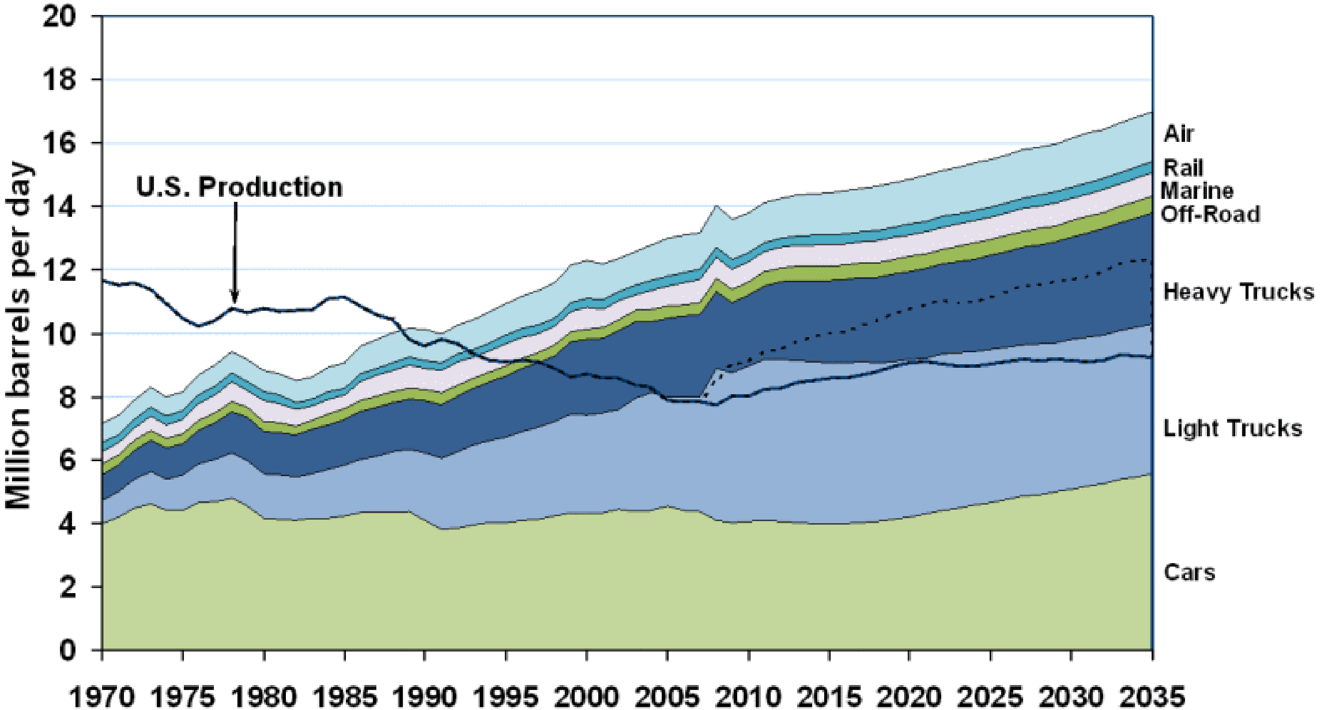
- Improve efficiency and reduce emissions for conventional gasoline and diesel engines
  - *A 10% reduction in weight yields a 6-8% improvement in fuel economy*

- Reduce dependence on imported oil



Source: *Transportation Energy Data Book: Edition 28* and projections from the Early Release *Annual Energy Outlook 2010*.

Why Lightweight?

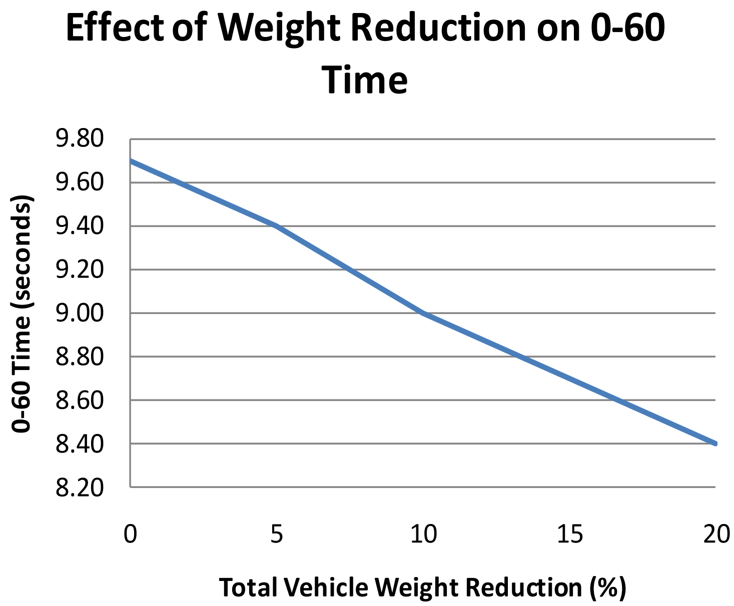
Customer Value Balancing Act

- Improve commercial viability of electric, plug-in hybrid, and fuel cell vehicles
  - Improve range for existing battery set

  Or
  - Maintain range with smaller battery set (reduced cost)

- Improve vehicle performance
  - Improve 0-60 acceleration without increasing engine size

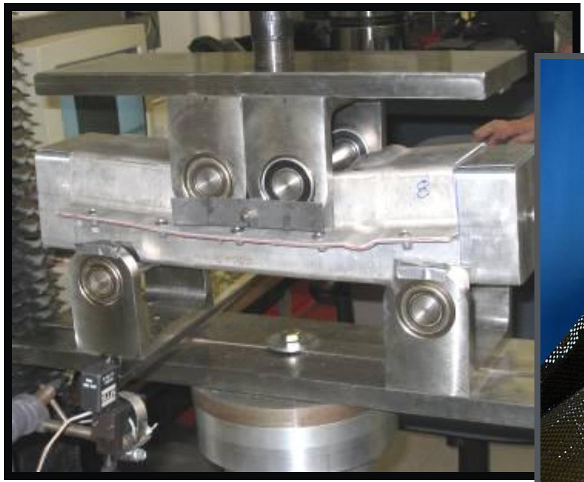
  Or
  - Maintain 0-60 acceleration while decreasing engine size



http://aluminumintransportation.org/downloads/AluminumNow/Ricardo%20Study_with%20cover.pdf

Why Not Lightweight?

- Gaps in light weight material technology (performance, manufacturability, cost)
- Sunk capital in metal forming equipment
- Limited production capacity of some light weight materials
- Perceptions of safety
- Preference for larger vehicles
- Limited recyclability



What is required for a 50% weight reduction?

Example Component Lightweighting

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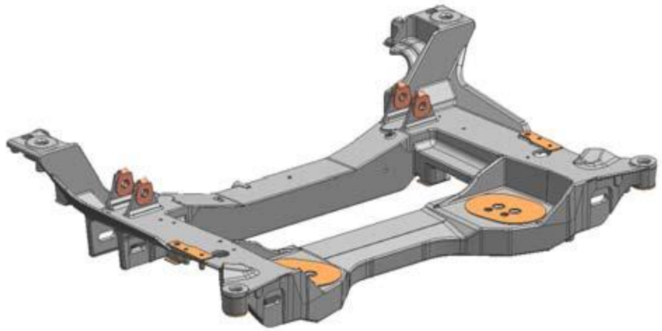
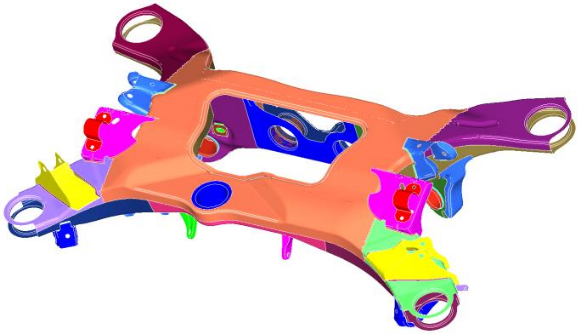
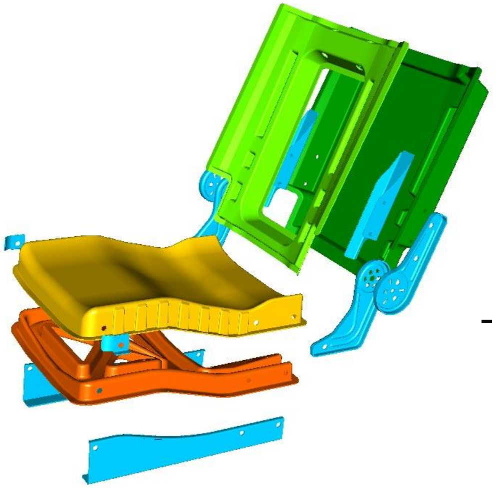


- Mg engine cradle for Corvette Z06
- 60% lighter than steel, 35% lighter than Al
- Single piece Mg casting vs. 28 piece steel assembly



- AHSS rear cradle for RWD vehicles
- 28% lighter than conventional design, no loss of stiffness
- Cost neutral



- Carbon Fiber Composite seat structure
- 58% lighter than standard design

- Mg engine block, bedplate, oil pan, and engine cover
- 28% lighter than Al version

Example System Lightweighting

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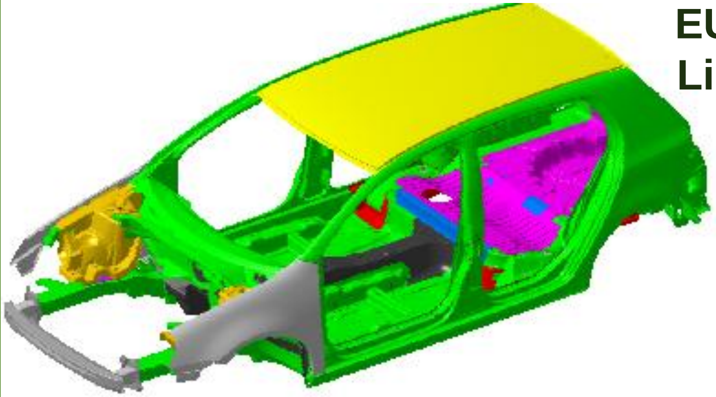


EU Super Light Car

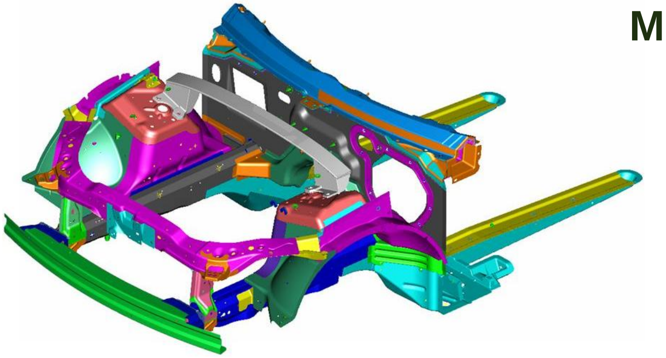
- Multi-material vehicle, Al intensive
- 30% weight reduction for BIW

Energy Foundation - Lotus

- AHSS intensive vehicle
- 16% weight reduction for BIW

PNGV

- Multi-material vehicles
- ~25% overall vehicle weight reduction



Mg Front End

- Mg intensive front end structure
- 45% weight reduction compared to steel
- 56% reduction in part count

50% Weight Reduction?

- Will not occur through optimization and trimming in existing designs
  - Tubular sections with holes, scalloped flanges, etc.
- Will not occur through material substitution in existing designs
  - Component *or* system level

→

- Will require material specific designs
  - The right design using the right material for the right application

- Unlikely to occur using existing vehicle composition
  - Aluminum, magnesium and composites all will play a larger role

→

- Will require advancements in multi-material technology
  - Joining, corrosion, modeling, manufacturing, cost reduction

How will we get there?

Research and Development Approach

Strategy and Road Map Development

- Identify technology gaps
- Establish performance targets
- Determine technology alternatives and milestones

Fundamental Research

-Fundamental Materials Science
- High Risk Research

Pre-competitive Research

-Applied Materials Science
- Cost and Manufacturing Research

Solicitations and Demonstrations

- Validate technology worthiness
- Identify new gaps and opportunities

Technology Transfer to Industry

Direct Commercialization by Industry

Topics Of Interest

Light Duty Vehicle - Materials Road Map

Heavy Duty Vehicle - Materials Road Map

Properties and Manufacturing

- Mg Alloys
- CF Polymer Composites
- Al Alloys
- AHSS
- Ti Alloys
- MMCs, Nano-materials, etc.

Multi-material Enabling

- Advanced Fusion Joining
- Solid State Joining
- MM Mechanical Fastening
- Low-cost Corrosion Prevention
- Lightweight Systems
- Non-destructive Evaluation

Modeling and CMS

- Process/ Property/ Structure Modeling
- Materials Informatics
- Dynamic Structural Simulation
- Detailed Process Modeling

Mg Alloy Development

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Key Technology Gaps

Gap: Rare Earth elements are required to achieve superior alloy properties for certain applications
- High temperature creep resistance
- High strength and ductility sheet (e.g. WE43)
- High energy absorption structures

Gap: Inferior ductility impedes use of cast Mg in most structural applications
- Ductility in actual castings is lower than in coupons
- Our understanding of the process > structure > property relationship is limited

Gap: Deformation at high strain rates is not well explored
Gap: Mg alloy set is very limited. Large sets of binary and ternary alloys are not explored at all.
Gap: Design methods for managing high anisotropy are not well established

Active Research

Non-RE High Performance Mg Alloys
Pacific Northwest National Laboratory

-Expanding on work done with BRL in the 1990's for Mg in interior "ballistics applications"
- Developing Mg extrusions with energy absorption comparable to 6061 Al
- Exploring low-cost process modeling method

Modeling of Complex, Ductile Mg HPDC
New Start

-Focusing on improved structure > property model development, including intrinsic and extrinsic defects
- Moving from empirical/curve fitting models to physics based models for ductility in HPDC
- Includes significant model validation

?

Carbon Fiber Composites Development

Key Technology Gaps

Gap: Use of high-grade PAN precursors limits cost to >$20/lb

- How can alternative precursors to PAN be converted to carbon fiber in a cost effective way?
- What processing innovations can also contribute to lower cost mfg of carbon fiber?

Gap: Properties of injection molded long fiber composites can not be accurately predicted

- How do conditions of molding influence Fiber length and distribution in a molded part?
-How accurately can one predict strength stiffness fatigue creep etc?

Gap: There is a continued need for validation (CF and Models) in increasingly complex applications

Active Research

Low Cost Carbon Fiber

Oak Ridge National Laboratory

- Study different low cost precursors
- Study innovative conversion processes to speed up and improve conversion of fiber
- Longer term transition innovation to ARRA demonstration line to validate cost models to lower the cost for industry to make decisions to commercialize

Predictive Engineering of Long Fiber Injection Moldable Composites

Oak Ridge National Laboratory, Pacific Northwest National Laboratory ,
American Chemistry Council Plastics Division
Autodesk Moldflow

- Validate existing models with progressively more complex shapes

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Advanced High Strength Steel Development

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Key Technology Gaps

Gap: Retained Austenite formation and stability in AHSS can not be controlled at levels required for 3rd Gen properties

- Austenite is likely a significant component of 3rd Gen AHSS
- Current method use high cost elements (Co, Ni, Mn) or processing

Gap: Microstructural damage during welding limits potential usefulness

- Many AHSS formulations rely on complex multi-phase structures
- Joint efficiency can be very low due to formation of cast-like microsctructures

Gap: Formability and springback modeling are nearly absent for AHSS
Gap: New high γ-α' SFE chemistries do not exist
Gap: High performance steels (without standard automotive cost limits) are not being widely researched

Active Research

Fundamental Study of γ-α Transition
Oak Ridge National Laboratory

-Using an in-line Gleeble at the Argonne APS to perform in-situ XRD during heating, cooling, and deformation
- Developing an improved understanding of the kinetics and mechanisms for tranisition

Friction Stir Welding of AHSS
Oak Ridge National Laboratory

-Focusing on improved structure > property model development, including intrinsic and extrinsic defects
- Moving from empirical/curve fitting models to physics based models for ductility in HPDC
- Includes significant model validation

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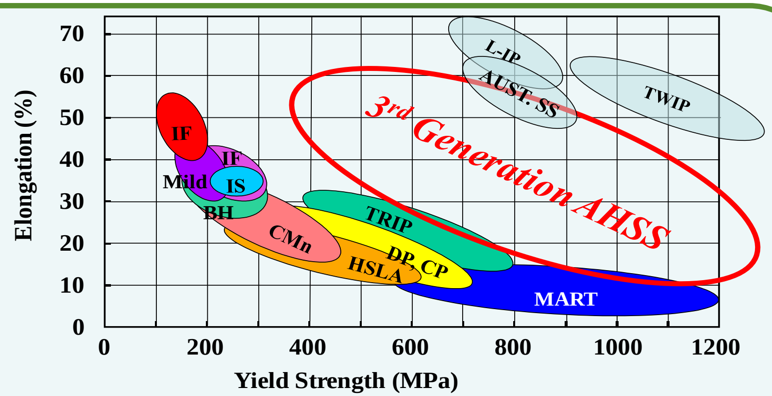

Multi-material Joining Development

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Key Technology Gaps

Gap: **Solid-state joining techniques for MM joints are not well characterized**

- USW and FSW both show promise
- Insufficient characterization and model development for auto deployment

Gap: **Mg/Al joints can not be riveted, limiting multi-material designs for certain applications**

- Mg room temperature ductility may be insufficient
- Elevated temperature processes are not developed

Gap: **Galvanic corrosion protection schemes add considerable cost**

Gap: **Structural adhesives are not prepared for use as primary/sole joining technique**

Gap: **Existing paint systems are not compatible with many light materials**

Active Research

USW and FSW of Mg to Steel

PNNL/ORNL

- Optimizing FSW parameters such as rotating speed, lateral speed, bit material and bit design
- Demonstrating high efficiency USW joints
- Developing initial physical models for predictive engineering and crash simulation

Efficient Mechanical Fastening of Mg/Al Joints

New Start

- Simulate SPR process for Mg/Al and determine process requirements for room temperature riveting
- Understand temperature profile required for elevated temp riveting
- Develop processing method to meet requirements

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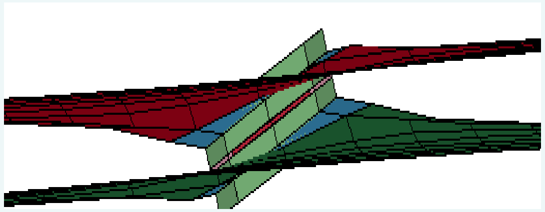


Modeling and ICME

Can we use computational materials science and engineering to solve light weight materials engineering problems more efficiently?

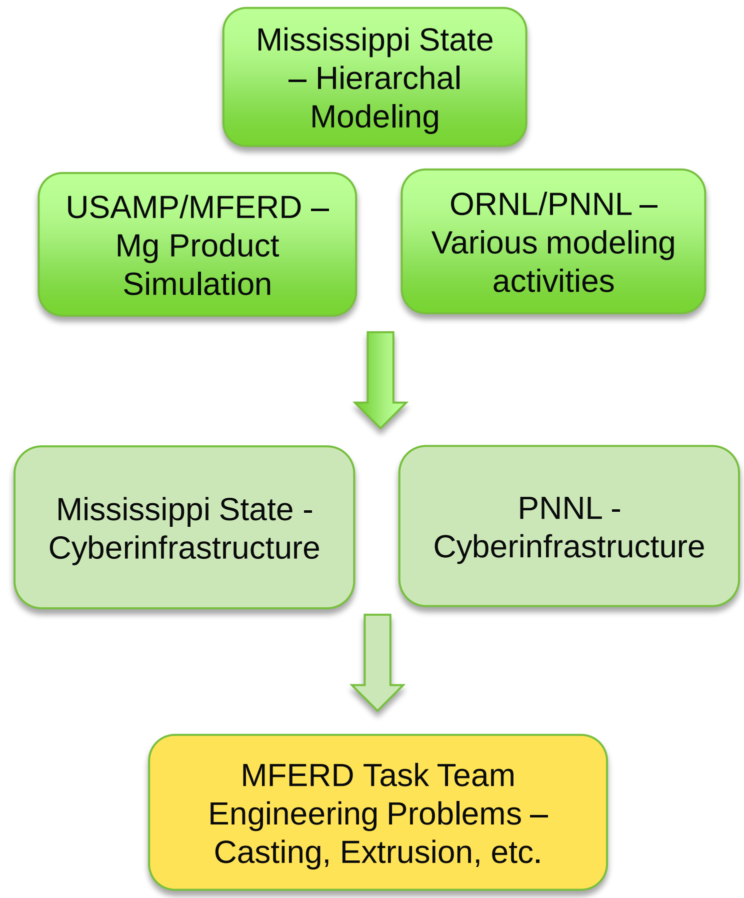
Key Organizational Gaps

Gap: **Ongoing activity in "ICME" is occurring throughout the government, industry, and academia but is difficult to coordinate**

Gap: **Mutually interesting foundational engineering problems have not been identified**

Gap: **Balance between competitive investment and open development is difficult to establish**

Active Research



Upcoming Activities

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ARRA Funded Low-cost Carbon Fiber Line

- A $34.7M ARRA funded user facility currently being installed at ORNL to develop new carbon fiber manufacturing techniques.
- Supports development and commercialization of carbon fiber that can be manufactured at $5/lb

Vehicle Technologies Solicitation NOI

- The Vehicle Technologies Program has issued a Notice of Intent for an upcoming Broad Agency Announcement
- Three topics in Lightweight Materials
  - Low Cost Development of Magnesium from a Domestic Source
  - Development of Low Cost Carbon Fiber
  - Demonstration Project for a Multi-material Light Weight Vehicle as part of the Clean Energy Dialogue with Canada

Additional Information

- Annual Reports
  http://www1.eere.energy.gov/vehiclesandfuels/resources/fcvt_reports.html
- Notice of Intent
  http://www.netl.doe.gov/business/solicitations/NOTICE%20OF%20INTENT.pdf
- Annual Merit Review Presentations
  http://www1.eere.energy.gov/vehiclesandfuels/resources/proceedings/index.html

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Questions?